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Dredging Research Technical Notes

Production Meter System Evaluation on the Dustpan Dredge *Jadwin*

Purpose

This technical note describes the experiences and results of the use of a production meter system on the US Army Corps of Engineers dustpan dredge *Jadwin*. Data interpretation and usage, along with lessons learned, are included in the information and will prove helpful to potential and new users of production meter systems.

Background

Production meter information can be used to increase dredge production and improve overall dredging efficiency. The data also can be used to improve the understanding of the dredging process and the effect of specific parameters on an individual dredge. As part of the Dredging Research Program (DRP) work unit "Production Meter Technology," a laboratory evaluation of production meter components was conducted (Pankow 1989). This evaluation was followed by a field demonstration in which a production meter system was installed on a dredge to evaluate system reliability, repeatability, and usefulness under actual dredging conditions. This technical note summarizes the lessons learned in the installation and use of a production meter and illustrates some of the ways in which the data can be used. Production meter accuracy will be addressed in a separate field exercise on a hopper dredge in which all the material can be captured in the hopper and measured.

Additional Information

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Introduction

In a cooperative research effort, the US Army Engineer District, Vicksburg, encouraged Dredging Research Program researchers to use the *Jadwin* to gain field experience with the installation and use of a production meter system. A production meter system consists of a density gage; a velocity meter; an easy to visualize and understand output display; and a means of recording, storing, and totaling the data. Since this was to be a temporary installation, the decision was made to use a doppler velocity meter which, along with the nuclear density gage, is clamped to the exterior of the discharge pipe. The use of a magnetic velocity meter requires the installation of a specially lined pipe section containing the velocity sensors. These are custom manufactured and are not usually available for temporary use. The acoustic doppler meter is frequently used on pipeline dredges, and its use on the *Jadwin* provided the opportunity to observe its performance.

The *Jadwin*

The *Jadwin* (Figure 1) is a dustpan dredge operated by Vicksburg District on the Mississippi River, generally between the mouth of the White River near Rosedale, Mississippi (river mile 599 above Head of Passes (AHP)), and Kenner, Louisiana (river mile 115 AHP). The dustpan head is fitted with numerous water jets to loosen and fluidize the sediment being dredged. The slurry is discharged against a baffle plate at the end of a 1,000-ft-long floating discharge line (Figure 2).

The production meter was used to evaluate the effect of pump speed and water jet pressure on dredge production. In addition to removing sediment from the navigation channel through the pipeline, some other process associated with the water jet fluidization of the sediment appears to be responsible for material movement. On this dredge, evaluating meter accuracy would be impractical because there was no means of verifying the meter

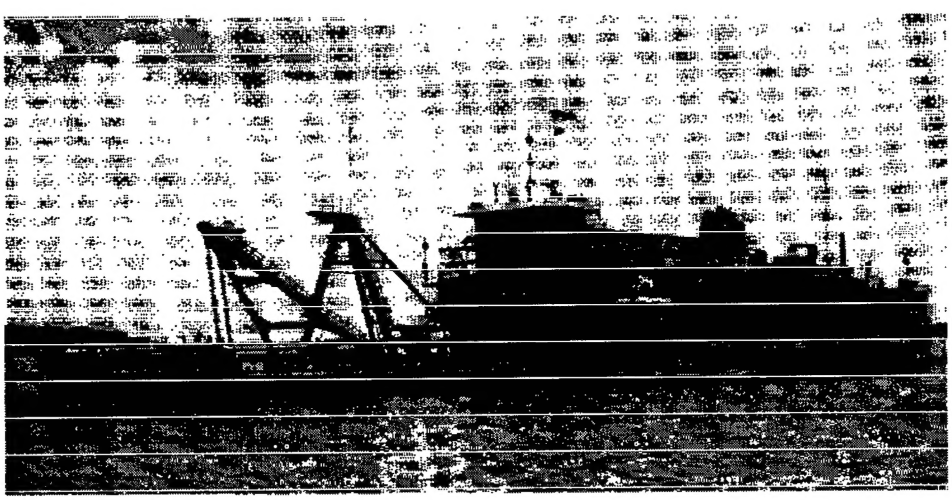

Figure 1. Dustpan dredge *Jadwin*

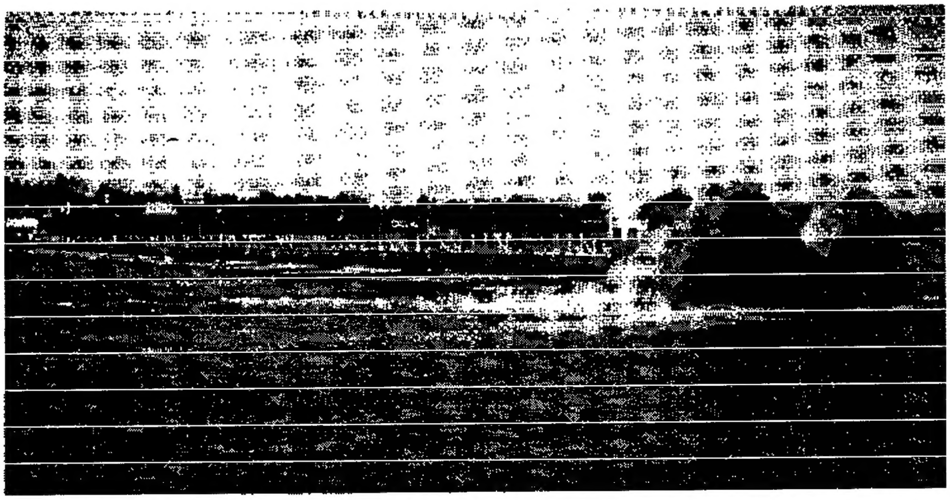

Figure 2. ***Jadwin*** **discharge line**

results. Collection of the dredged material in a confined site in which it could be measured occurred only once when, unfortunately, the meter was not operational. The production meter measures only that material which passes through the discharge pipe, while the pre- and postdredging survey measures the total amount of material removed (or deposited) in the channel through both direct dredging and river action. The data were evaluated for repeatability and reliability and were compared to the dredge logs to determine how closely the production meter results replicated the volumes determined by the dredge logs.

Installation

The installation of the production meter system provided an opportunity to gain dustpan dredge and production meter operational understanding and experience. A contract was awarded to DWS Inc. in May 1989 to lease a production meter system consisting of a Berthold nuclear density gage, a Berthold signal processor and production calculation unit, a single sensor Polysonics doppler flowmeter, a vertical bar output display, and a dot matrix printer. Initial installation aboard the *Jadwin* took place in mid-August 1989.

In the interim, a Nuclear Regulatory Commission (NRC) license was secured for the radioactive source (2,000-millicurie Cesium-137) housed in the Berthold nuclear density meter. Specific dredge plant and slurry information was required to properly size the radioactive source and flowmeter sensitivity. Information on dredge pipe size, material, and orientation (horizontal or vertical), sensor and control unit location (outdoors or indoors), available power, and instrument cable length were supplied to the contractor. Additional information characterizing the dredged material (slurry type, abrasiveness, homogeneity, and air/gas entrainment) solids and liquid phase, and specific gravity was required. Desired output units of measurement, accuracy, alarms, and response time information also were included in the contractor's information survey. During this time several planning

and coordination meetings were held between the DRP Principal Investigator (PI), the Vicksburg District and *Jadwin* key personnel, and the contractor to share information and plan how the production meter information would be used. Previous work (Pankow 1989) with production meter components and systems enabled the PI to anticipate potential areas of conflict.

The initial installation of the production meter system took place in mid-August 1989 while the dredge was working in the Mississippi River below Baton Rouge at Red Eye Crossing (river mile 223.4 AHP). The installation did not interfere with the dredging process since all sensors were mounted on the outside of the discharge pipe. The installation was accomplished by an NRC-licensed field service technician from Berthold and the DWS contractor, with assistance from the *Jadwin* Chief Engineer and electronics technician. Installation of the density gage was difficult because the components and mounting frame were mounted on the overhead discharge pipe, requiring personnel to work from ladders. The density gage was installed approximately 10 pipe diameters (26 ft) from the first 90-deg pipe elbow on the deck portion of the discharge line, and it was oriented 70 deg from the horizontal (instead of the preferred 45 deg) because of room constraints (Figure 3). The velocity gage was mounted between the 7 and 8 o'clock positions on the discharge pipe about 4 ft downstream from the density gage. The signal cables were run from the sensors to the wheelhouse and connected to the Berthold signal processor unit.

The Chief Engineer and the Dredge Inspector received operating instructions and meter information. Keys to secure the radiation source were given to the Captain, and radiation safety instructions and information were provided to the Captain and key dredge personnel.

Calibration

The velocity gage was factory calibrated on a pipe section of the same material and size as the *Jadwin* for a velocity range of 0 to 26 ft/sec with 4- to 20-mA output signal. Only one measuring point was necessary for start-up of the density gage, but the system has the capability to accept additional calibration values for increased accuracy. A density gage is best calibrated by passing two materials of known density through the pipe, ideally the carrier fluid and the dredged slurry. On the *Jadwin* it is difficult and dangerous to capture a sample from the end of the discharge pipe as it hits the baffle plate. It also would not be truly representative of the average material passing through the pipe since heavier material moves along the bottom of the pipe while the lighter material moves above it. Therefore, the density meter was calibrated with river-water carrier fluid. With the dredge pumping river water, an automatic averaging program calculated the average pulses detected. This was equated to a measured volume and weight of the same water sample. Another required input value is the in-situ density of the bottom material. For the type of river dredging done by the *Jadwin*, a simple field procedure was used to provide a good approximation of in-situ density. This procedure can only be used with predominantly sandy material containing very little mud or silt.

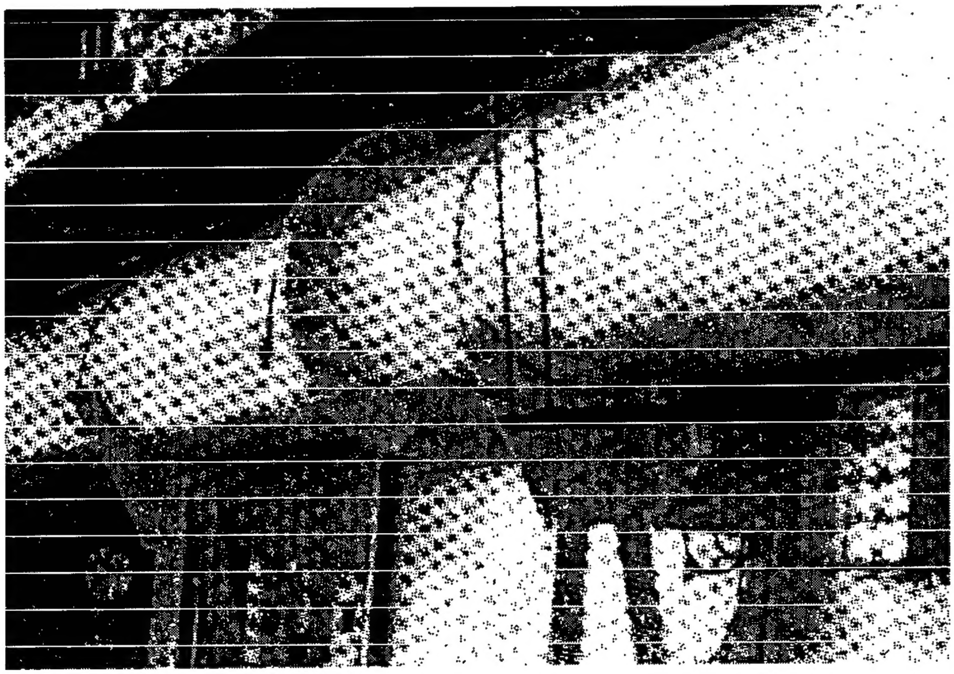

Figure 3. Nuclear density gage and doppler velocity meter

Problems and Solutions

From initial installation in May 1989 through the end of the field test in December 1990, actions were taken to improve, refine, and repair individual components of the system. The problems encountered and solutions enacted are grouped according to system component rather than in chronological order.

Velocity Meter

The single-sensor Polysonic velocity meter was initially calibrated for a velocity range of 0 to 26 ft/sec. The *Jadwin* pipeline velocity averages about 22 ft/sec, but varies up to 26 to 28 ft/sec. The meter was returned to the factory for recalibration for a velocity range of 0 to 32 ft/sec. This enabled the gage to operate closer to midrange and prevented the gage from exceeding the scale range when velocities reached 26 ft/sec or greater. In July 1990, after operating flawlessly since installation, the velocity meter began reading an erroneous slurry velocity of 7 ft/sec when the dredge was pumping at normal velocity of 20 to 22 ft/sec. After troubleshooting of all parts of the system and circuitry (according to instructions received with the velocity meter and from telephone conversations with the service technician), the velocity meter transducer and transmitter were returned to the factory for further evaluation and repair. The meter was initially repaired with some adjustments to the circuit board. After a few weeks back in operation, the same problem reappeared; this time the entire circuit board was replaced. It is possible that the 4- to 20-mA driver circuitry became temperature sensitive or that the vibrations of the dredge affected the electronic circuitry. The inside of the transmitter box was dry and clean, so internal contamination

does not seem responsible. After replacement of the entire transmitter circuit board, the velocity meter again performed well. The repairs were made at the Polysonics facility and were performed under the instrument warranty.

Density Gage

The Berthold nuclear density gage has three basic parts—the nuclear source, the detector, and the signal processor massflow unit. No problems were encountered with the nuclear source. The shielding and housing met all radiation safety requirements as demonstrated by the results of all radiation "wipe tests." As a precaution for periods when the density gage is not in use, a radiation shutter can be closed to safely isolate the radiation source. A problem developed when the shaft separated from the shutter while in the closed position. This rendered the density meter safe but useless and required the services of the field service technician for correction. The shutter assembly was replaced with some minor modifications to accommodate more frequent opening and closing than is normally encountered in the process industry for which the meter was originally designed.

The original radiation detector of the density gage had a counting range of 800 to 50,000 pulses/sec and worked very well when the dredge was operating at Red Eye crossing in the Mississippi River. When the dredge moved to the Arkansas River and was dredging more dense sediment in shallower water, a density meter probe failure message appeared. The problem was solved by the installation of a second detector with a counting range of 0 to 5,000 pulses/sec. The density of the Arkansas River material was giving counts of 260 to 300 pulses/sec which underranged the original meter, resulting in the probe failure message. A further problem developed when the second detector continuously failed to operate properly, reading a constant density value of 1.4 even with the dredge pumping only water. This was traced to a factory ratio setting in the detector that divided all radiation counts by four. The divided counts became very low and resulted in underranging the circuitry at the specific gravity limit of 1.4. This problem was solved with the installation of a third detector with proper counting range and ratio settings. The detector problem solution was a cooperative effort between the Berthold and US Army Engineer Waterways Experiment Station (WES) Instrumentation Services Division (ISD) engineers. The detectors were replaced by Berthold at no cost to the user, and the replacement was performed by ISD engineers since the source was not involved and the radiation shutter remained closed throughout the repair.

The Berthold signal processor massflow unit receives input signals from the velocity and density meters and outputs a calculated production value in metric tons per hour. Misunderstandings due to incomplete communications between the principal investigator, the contractor, and the instrument manufacturer resulted in the need for a printer serial interface card and other electronic parts before the massflow unit and output display would operate properly. The signal from the velocity meter was needed by the massflow unit as well as the output display, but the contractor had not provided a means of splitting or repeating the signal to supply both needs.

This was addressed in a subsequent visit to the dredge, and ultimately all signal needs were met.

The operation of the signal processor massflow unit depended upon the input of certain values to be used in the production rate calculation. Some values such as pipe diameter remain constant, but others such as water and in-situ density may vary from site to site. The instructions for data entry were straightforward, but required time and experience before confidence was attained. There also was a sequence of operations that, if not precisely followed, could present problems in the operation of the massflow unit. Although not difficult to use, the unit was not user-friendly and, other than the printer to record density and production rate data as they were gathered, there was no means to store data for further evaluation.

Computer Data Acquisition and Storage

One of the objectives of the field test was to evaluate the performance of the production meter system. This presented the need to store the data so comparisons could be made. Using the expertise of the ISD engineers, an interface between the massflow unit and a GRID portable computer was made. Software was developed that enabled the user to operate the system by answering six simple questions. The software gathered the velocity and density values from the massflow unit and calculated total production in cubic yards and production rate in cubic yards per hour of in-situ material rather than metric tons of solids. This system worked very well and produced several good data sets for evaluation. Other than some minor program improvements, the computer and interface components performed as designed.

Output Display

An easy to visualize and interpret output display of slurry density, velocity, and production rate was important for the acceptance of the production meter system by the user. Since a crossed-pointer display unit was not available on a rental basis, a compact display of three bar meters with backlighting for nighttime visibility was installed. Unfortunately, these meters provided percent of scale rather than units of density, velocity, and production. Another problem was that the backlighting was too bright, with no means of dimming, for the darkened pilot house during nighttime dredging. This display was replaced by three 4- to 20-mA analog display meters (dial gages) mounted in triangular fashion (Figure 4) and calibrated for velocity (0 to 32 ft/sec), density (1.0 to 1.4 specific gravity), and production (0 to 100 cu yd/hr × 100). They were not backlit and were located about eye level and to the right of the dredge operator. This output display was in addition to the computer display screen, which was located behind the dredge operator, with the computer lid usually closed during nighttime dredging.

The system included a small printer that could either print the screen as the values were recorded or print files from the data acquisition program when that program was not running. Installing a quiet printer would be advisable if data are to be printed while the dredge operator is working.

Production Meter Data

With the originally installed system, the production meter information of slurry velocity, density, and production rate were available on the analog output display. The massflow unit digitally displayed the density or production rate, which could be recorded on the printer when desired. With the enhancement of the system to include a small portable computer with data logging and storing software, the production meter system met the needs of all data users. The capability to retrieve and analyze data to properly evaluate meter performance was achieved.

In addition to the analog output display, the software would display on the screen the date, time, slurry specific gravity, calculated instantaneous production in cubic yards per hour, slurry velocity in feet per second, and total cubic yards dredged since the counter was reset to 0. A program called PMETER was used to acquire the density and volume flow data from the massflow unit. It calculated production rate and total yardage, displayed information to the screen, and stored data in two separate files. Data for meter evaluation was recorded every 10 sec in a data file, while half-hour values of instantaneous velocity, density, production rate, and total cubic yards of dredged volume were recorded in a log file for the dredge inspector's use. At midnight the program automatically closed the current files and opened a new set of files for the next day. Therefore, each file covered a 24-hr period from midnight to midnight. Data could be recorded as often as every second or as infrequently as 9,999 sec (2 hr 46 min). The time intervals of 10 sec and 1,800 sec (30 min) for the data and log files were recommended so that the completed 24-hr files would fit on one standard

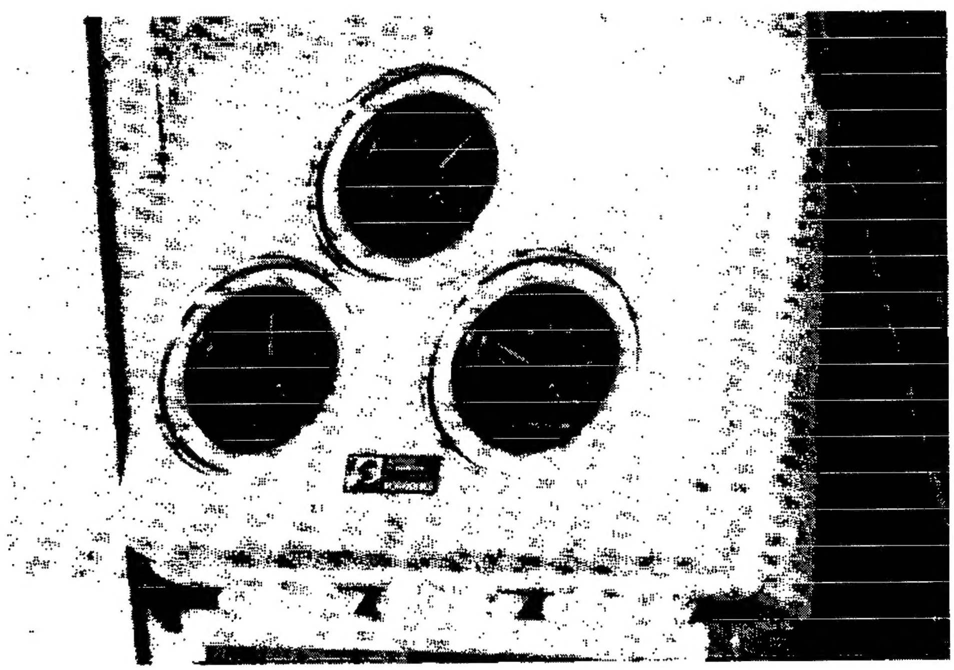

Figure 4. Production meter readout display

1.44-megabyte high-density 3.5-in. diskette. This enabled the data to be easily transportable. One month of continuous data could be stored on the computer hard disk before it had to be moved to another sector or floppy diskette.

Data Input Values

Some initial information must be entered into the massflow unit so the computer can identify values for the variables in the production calculation equation, establish timing parameters, and set the counters. Once the values of pipe diameter, sediment particle density, carrier water density, and maximum and minimum values for the 4- to 20-mA density and velocity signals are entered into the massflow unit, they generally remain unchanged. Information of file name, data recording intervals for the data file, log file and screen display, in situ density of material, and initial condition for the totalizer are input to the PMETER program.

Data Analysis

The log file, which contained 48 lines of data, was quickly reviewed for reasonable values of density, velocity, and production. Improperly functioning meters were easily identified. The data file contained 8,640 lines of data and was processed with a four-step computer procedure. The first three steps involved copying, listing, and formatting the data so they could be used in the fourth step, which was a mathematical interpreter used to plot the statistical data.

The data files were analyzed using this procedure and then compared to the Daily Dredge Location Report prepared by the *Jadwin* Dredge Inspector. There were considerable differences between the two reporting methods of production rate and the daily yardage dredged. The Daily Dredge Location Report values of yardage dredged and average production rate were always higher than the production meter calculations. This difference can be explained because the production meter measures only the sediment that passes through the discharge line, while the Daily Dredge Report estimates all the material removed from the channel with both direct and indirect (fluidization/agitation) dredging. The *Jadwin*'s average production rate for the period May 1 through May 17, 1990, calculated by the production meter was 2,736 cu yd/hr, while the average rate from the Daily Dredge Reports was 3,429 cu yd/hr. The difference may be due to indirect dredging and reporting system inaccuracies. This difference appeared to vary with location and type of sediment, but no statistical analyses were performed. For a dustpan dredging operation, allowances must be given for the amount of material that may be removed by the water jets on the dustpan head.

There also were differences in the pumping time/lost time recorded by the Dredge Inspector and the values calculated by the software. The Dredge Inspector uses the lost time values recorded by the dredge operator, while the software was programmed to regard density levels below a designated amount as nonproductive time. The value used in the software was low but arbitrary and, ultimately, incorrect. The software will be modified and reapplied to the data, and these results will be included in the final report. This

ability to continuously monitor slurry density enables the verification of dredging time and time lost (to activities such as clearing the head, allowing river traffic to pass, and resetting the anchors) and is a valuable source of information when monitoring a contract dredge.

Dredging Parameter Test

The production meter information was used to better understand the effects of dredge pump speed and water jet pressure on the *Jadwin*'s dredging ability. With the water jet pump operating in the normal mode of 70 psi at 1,000 rpm's, the dredge pump speed was varied from 150 to 190 rpm's and production meter data of slurry density and velocity were recorded. The data show that slurry velocity is initially directly related to dredge pump speed, but reaches a maximum and then remains constant as shown in Table 1.

Table 1

Influence of Dredge Pump Speed on Production

Pump rpm's	Density (specific gravity)	Slurry Velocity ft/sec	Production Rate cu yd/hr
150	1.15	17.5	2,400
160	1.18	17.7	2,900
170	1.16	18.7	2,700
180	1.22	21.0	4,300
190	1.20	21.0	3,727

The slight decrease in slurry density at 170 rpm's is inconsistent, and even though the slurry velocity increased (from the 160-rpm value), a decrease in production rate is observed. These data illustrate that density is the more important factor in the production equation.

To evaluate the effect of water jet pressure on dustpan dredging, the water jet pump pressure and speed were varied from 0 to 70 psi with the dredge pump speed held constant at 190 rpm's. The data listed in Table 2 and displayed in Figure 5 show that a water jet pump pressure between 16 and 38 psi (500 to 750 rpm's) is needed before a pipeline slurry density above 1.1 specific gravity can be obtained. There appears to be a minimum water jet pump pressure necessary to fluidize and expand the sediment for creating a sediment environment for the dustpan head to dredge. Figures 5 and 6 illustrate the inverse relationships between velocity and density, and velocity and production, while Figure 7 shows the direct relationship between density and production.

Table 2

Influence of Water Jet Pump Pressure on Production

Pressure psi	Density (specific gravity)	Slurry Velocity ft/sec	Production Rate cu yd/hr
0	1.05	23.1	1,240
6	1.09	22.6	1,945
16	1.09	22.3	1,867
38	1.15	21.7	2,930
50	1.17	21.4	3,274
70	1.19	21.2	3,728

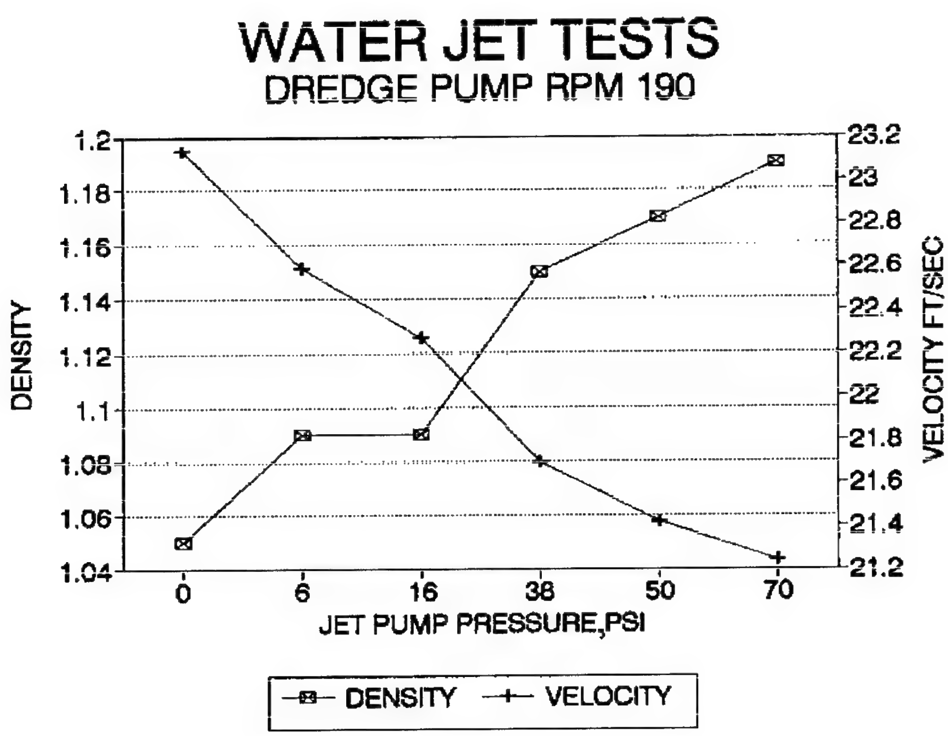

Figure 5. Jet pump pressure versus slurry density and velocity

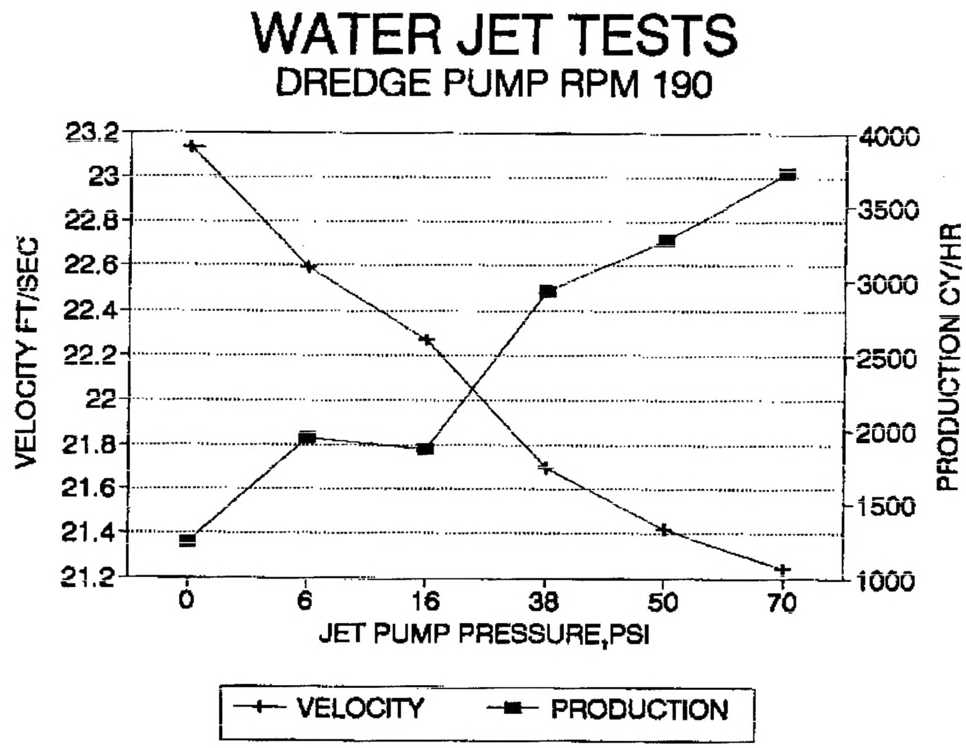

Figure 6. Jet pump pressure versus slurry velocity and production rate

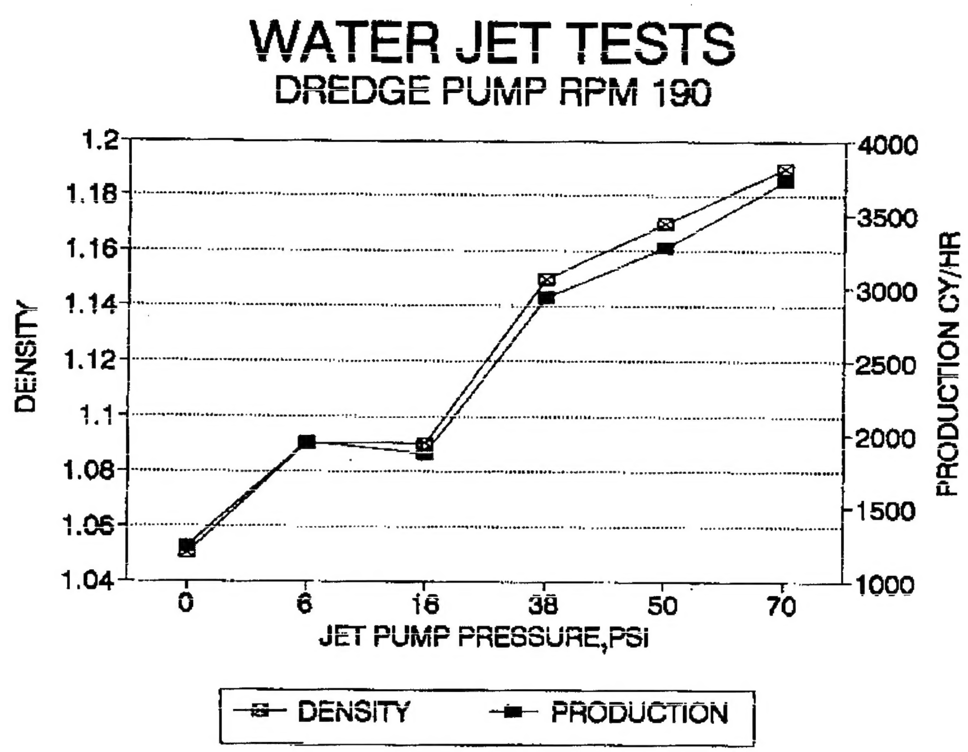

Figure 7. Jet pump pressure versus slurry density and production rate

These dredging parameter tests illustrated that the current dredging practices employed on the *Jadwin* are well suited for the dredging equipment. The use of production meter data to customize dredging practices for specific site characteristics of sediment and water depth can make the dredging process more uniform and efficient.

Summary

A production meter system consisting of a doppler velocity meter, a nuclear density gage with signal processor and production calculation unit, an analog output display, and a printer was installed on the dustpan dredge *Jadwin*. It was enhanced with computer hardware and software to record and store production meter data. The purpose of this effort was to evaluate the reliability and repeatability of the system and its components. The data proved to be consistent and reasonable. Instrument malfunctions were easy to recognize and, once understood, uncomplicated to correct. The meter manufacturers were available and involved, and they corrected all instrument problems in a timely manner.

The data were used to better understand the effects of water jet fluidization and pump speed on the dredging process. Preliminary data from one location and depth indicated that direct dredging accounted for about 80 percent of the total dredging for that time period and location. Data from other locations indicated a value as low as 40 percent. The data also were used to identify the jet pump pressure needed to produce the necessary level of sediment fluidization for efficient dredging. It was demonstrated that slurry velocity and dredge pump speed are directly related and reach a maximum value, while slurry velocity remains constant even with an increase in pump speed.

Data were gathered that illustrated the direct relationship between density and production, and the inverse relationships between slurry velocity and density, and slurry velocity and production. As the density of the slurry increased, the velocity decreased with the energy being used to move the more dense material through the pipeline.

These dredging parameter tests illustrated that current dredging practices employed on the *Jadwin* are well suited for the dredging equipment. The use of production meter data to customize dredging practices for specific site characteristics of sediment and water depth can make the dredging process more uniform and efficient.

These observations were based on preliminary data recorded throughout the dredging season at selected times when the system was working well. To fully substantiate these findings, further tests should be conducted over longer time periods. The final values undoubtedly will vary with the specific dredging sites and conditions, but the trends identified above are expected to remain essentially the same.

Recommendations

The experience with the production meter system on the *Jadwin* provided a beneficial learning experience. The information in this technical note will enable others to avoid similar problems and proceed quickly with the planning, purchasing, installing, and functioning phases of operation. Some areas of consideration are:

- Include the users of the equipment and the data in the entire planning process. Each user may have different needs, and all needs should be addressed.
- Decide on the units of measurement for the output gages and identify the realistic ranges of readings that will be obtained.
- Be sure the contractor understands the individual needs and provides an explanation of all equations used to calculate dredge production.
- Have the output readout display calibrated so the normal operating range is about midscale and specify the scale of values such that changes of 2 to 5 percent can be detected.
- Keep the output display uncomplicated so the primary user can easily observe and understand the readings.
- Decide where the output gage(s) will be located; identify the acceptable parameters of instrument height, light, noise, and other parameters.
- If the system is enhanced with computer recording capabilities, use software that can be easily modified and that will meet all users needs.
- Fully understand the operation and maintenance of the equipment and take advantage of manufacturers' training courses when offered.
- Start early in the purchasing process to fulfill the NRC requirements for a General or Specific License.
- Verify that meter service is available and that the manuals on the dredge are the same as the ones used by the service technician; determine the hours when this service is available.

Preplanning and good communications with the instrument vendor are essential to minimize problems that may arise during the installation of new equipment.

Reference

Pankow, Virginia R. 1989. "Laboratory Tests of Production Meter Instruments," Dredging Research Technical Note DRP-4-01, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

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